European Journal of Advances in Engineering and Technology, 2018, 5(12): 939-951



Research Article

ISSN: 2394 - 658X

Techno-Economic Analysis of a Hybrid Pv/Wind/ Diesel System

R.O. Okeke, M. Ehikhamenle

Department of Electrical and Electronic Engineering, University of Port Harcourt, Choba, Rivers State, Nigeria Email:mattinite4u@yahoo.com,remyokeke@yahoo.co.uk.

ABSTRACT

Hybrid renewable energy systems are increasingly being utilized to provide electricity in remote areas especially where the grid extensions is considered too expensive. This research presents the results of techno-economic analysis of hybrid system comprising of solar and wind energy for powering six selected area in each state in the south-south geopolitical zones of Nigeria. All the necessary modelling simulation and technical economic evaluation are carried out using the assessment software package HOMER (Hybrid Optimization model for Electric Renewable). Two best optimal systems configuration namely PV-diesel-battery and PV-wind-diesel-battery-systems are compared with the conventional standalone diesel generators (DG) systems. Finally the environmental benefit of hybrid systems over the conventional standalone diesel systems is described.

Key words: Hybrid, Renewable, Solar, Optimization, Generator, Grid

INTRODUCTION

A sufficient energy supply is indispensable for sustainable techno-economic development of any under developed or developing or developed nation [1]. A Nation will continue to be under developed and retard growth beyond the subsistence level without an appreciable access to energy supply [2]. About sixteen percent of the global population which is estimated One billion two hundred people around the world mostly in small villages and towns in developing countries currently lack grid-based electricity services according to the World Energy Outlook, (WEO, 2016) [3]. Many more suffer from supply that is of poor quality. More than 95% of those living without electricity are in countries in sub-Saharan Africa and developing Asia, and they are predominantly in rural areas (around 80% of the world total) [4]. While still far from complete, progress in providing electrification in urban areas has outpaced that in rural areas two to one since 2000, (WEO, 2016) [3].

The Nigerian Association of Energy Economists (NAEE) has said that about 75 per cent of Nigeria's 170 million people still live without access to regular electricity supply [5]. NAEE said that despite statistics indicating that 45 per cent of the country's population is currently connected to the national grid [6]; regular supply is still restricted to just about 25 % of the population [1]. According to the association, most of the people with access to electricity are found within the urban areas of the country, thus leaving citizens in the rural areas with less access to electricity supply [2]. NAEE therefore raised concern on economic redundancy in these parts of the country, adding that despite the importance of energy to economic development, large proportions of Nigerians still lack access to electricity [7]. The National President of NAEE, Prof. Wumilledare, who briefed journalists in Abuja on the occasion of the '2015 World Energy Day', pointed out that energy has contributed greatly to the transformation of the world and has provided comfort to the human race[8]. Iledare however noted that the association was concerned that majority of Nigerians do not have access to energy, stressing that for those with some form of access, availability and quality still remain major issues to contend with [9]. Even the Forty-five percentage population connected to the grid, incessant power supply has always being the situation in most cities in Nigeria due to the poor power situation, thus making electric energy consumers to supplement grid connections with self-powered generation(through diesel/petrol electric generators). Other than grid unavailability, energy supply mix in Nigeria is dominated by fossils sources [10].

HOMER found to be the most widely used optimization tool for modeling the HPS in this work [5]. It is a sophisticated tool or computer model that facilitates design of stand-alone electric power systems and performs simulations to satisfy the given load demand using alternative technology options and resources availability [11]. HOMER simulates a HPS,

based on the hourly time stepped load data profile and the average monthly weather data of the specific location over a period of one year [7].

EXPERIMENTAL METHOD

Fig 1 shows daily load profile for each month. Measured hourly load profiles are not available for the selected sites; load data were thus synthesized by specifying typical daily load profiles. Characteristics of the load categories are: Domestic load: For each household, the load is based on 4 energy efficient compact fluorescent lamps (20 W each), 2 ceiling fans (30 W each), 1 television (80 W) and 1 radio (10 W). The load demand is approximately 108kWh/day. Social infrastructure: This includes the demand for the primary health center, public primary school, community hall and shops. The load demand is approximately 15kWh/day



Fig. 1 Monthly AC primary load profile Table -1 Estimated electricity demand for each rural community

Load	No in use	Power (watt)	January to	December
			(hr/day) (wa	att-hr/day)
Category A: Domestic load				
Lighting	4	20	8	640
Television	1	80	4	320
Radio	1	10	12	120
Ceiling fan	2	0	18	1080
Total for 50 household				108000
Category B: Social infrastructural				
Load				
Primary health center				
Lighting (CFL)	6	20	10	1200
Refrigerator	1	600	16	9600
Television	1	80	6	480
Ceiling fan	2	30	12	720
Total				12000
Public primary school				
Lighting (CFL)	7	20	4	560
Ceiling fan	1	30	6	180
Total				740

•	Community hall and shops				
	Lighting				
	Ceiling fan	10	20	5	1000
	Television	4	30	7	840
	Total load	1	80	6	480
	Miscellaneous load				2320
	Total load consumption		80	6	480
	-				123540

Solar radiation

Table 2 shows the solar irradiation for each selected location as obtained from the Solar Electricity handbook global satellite database (www.solarelectricityhandbook.com/solar-irradiance.html), Using solar panel direction: East South East (67.5'). The solar radiation data for all six sites were obtained according to their respective latitude and longitude, as earlier presented in Table 1 and measured by precision pyrometer.

Month			Village			
	Iwofe	Wilberforce island	Ikpa road	Okada	EdibeEdibe	Abraka
January	5.14	5.19	5.47	5.37	5.55	5.27
February	5.18	5.19	5.53	5.43	5.59	5.27
March	4.74	4.82	5.25	5.28	5.28	5.12
April	4.53	4.78	5.02	4.99	5.02	4.98
May	4.16	4.31	4.65	4.67	4.71	4.48
June	3.48	3.53	4.24	4.16	4.29	3.69
July	3.19	3.22	3.79	3.51	3.83	3.25
August	3.37	3.45	3.71	3.51	3.63	3.76
September	3.63	3.54	4.22	4.33	4.27	4.21
October	3.63	3.54	4.22	4.33	4.27	4.21
November	4.16	4.33	4.79	4.94	4.79	4.92
December	4.90	4.97	5.23	5.19	5.27	5.08
Average	4.176	4.239	4.677	4.643	4.708	4.520

Wind speed

The monthly average wind speed data for an average of ten (10) years were obtained from Time and Date Weather global database (www.timeanddate.com/weather/nigeria) on the latitude and longitude of the different selected villages using anemometer at 10m above sea level. The annual average wind speed for each village is presented in Table 3. The wind speed from the selected site ranges from 2.9 to 6.9 m/s. The changes in the wind patterns occur as a result of earth's topography, bodies of water and vegetation cover. Observation of the wind probability and average monthly speed for a year, show that the peak wind speed occurs at 15.00hrs. The average wind speed of Iwofe village is shown in fig 2.

The wind turbine costing variables (initial cost, operation cost, and replacement cost) are similarly derived as for the PV array. Wind turbine operating costs comprise maintenance and replacement costs Maintenance costs for wind turbines can vary depending on the application, type of maintenance and wind turbine sizes. The wind turbine life is often assumed to be more than 20 years; therefore in many life cycle costing no wind turbine replacement will take place.



Fig. 2 Wind speed data for Iwofe village, Port Harcourt

	1	Table - 5 while speed	u uata tot til	e six villa	205	
Month			Villages	1		
	Iwofe	Wilberforce island	Ikpa road	Okada	EdibeEdibe	Abraka
January	5.4	5.4	3.6	3.4	3.6	4.3
February	5.6	5.6	3.8	3.1	3.6	4.3
March	6.0	6.0	4.0	3.8	3.8	4.5
April	5.6	5.6	4.0	3.6	4.0	4.5
May	5.1	5.1	3.6	3.6	3.6	4.0
June	5.1	5.1	3.4	3.1	3.1	3.8
July	5.8	6.9	4.0	3.6	3.6	4.7
August	6.5	6.5	3.6	4.0	3.4	4.9
September	5.4	5.4	3.4	3.4	3.1	4.3
October	4.7	4.7	3.4	3.1	3.4	4.0
November	4.5	4.5	3.1	2.9	3.1	3.6
December	4.7	4.7	3.1	2.9	3.1	3.6
Average	5.37	5.46	3.58	3.38	3.45	4.21

 Table -3 Wind speed data for the six villages

Components Data

The proposed hybrid systems consist of PV panels, wind turbines, diesel generators and other system components such as batteries, converters. The PV panel, wind turbine and diesel generator combined to harness the overall system output as well as to compensate for the unpredictable variation in RE sources from one zone to another.. Assumptions regarding components pricing and sizing as adopted in the proposed hybrid system, are expressed below;

- The capital cost and replacement cost of 1W of PV array were taken as \$3.0 and \$2.0 respectively (Price from ebay store). The lifetime of PV arrays was taken as 20 years. The de-rating factor that accounts for losses due to temperature effects and dirts on the PV modules surface was assumed as 90%, and the ground reflection of the modules were taken as 20%. Different sizes of PV arrays were considered to get the optimal size for each village.
- A generic model wind turbine with rated capacity of 3 kW is considered. The initial cost of one unit is taken as \$6000(Price from Amazon store). Replacement and operational maintenance costs were assumed as \$4000 and \$2000/ year respectively. In order to find an optimal size, different sizes of turbine options were analyzed. The operational lifetime of the turbine was considered as 20 years.
- The initial cost of AC diesel generator is \$133/kW, with a replacement cost of \$112/kW and maintenance cost of \$0.500/hr. The operating lifetime of a diesel generator was taken as 15,000 h with 30% load ratio.
- A bi-directional converter is added to maintain the flow of energy between the alternating current (AC) and direct current (DC) components. It functions as a rectifier when it converts AC to DC, and as inverter on the other way round. The initial capital and replacement cost of the converter used in this study were taken as \$1000/kW and \$800/kW respectively. The operational and maintenance cost is assumed as \$100/ year. The efficiency of the converter is assumed to be 90% that of rectifier is taken as 85% while the lifetime was taken as 10 years. Different sizes of converters were considered during the analysis.
- Generic 1Kwh lead acid type battery with rated 12 V nominal voltages and 1,156Ah capacity is considered in this study. The initial cost of one unit is \$150. Replacement and operational maintenance costs were assumed as \$110 and \$50/ year respectively. In order to find an optimal configuration, the battery bank was assumed to contain different number of batteries. Each battery string contains 8 batteries and the lifetime energy of each battery is estimated as 9645 kWh throughput.
- 20 years Project lifetime is considered in the simulation and has operating reserve that accounts for sudden spikes in the system, Nominal discount rate of 10%, excepted inflation rate of 2% and hence unpredictable output.
- Maximum hourly load of 2% is considered as the capacity shortage factor (CSF); this shows the amount of time to which the system will not be able to meet the load requirement including its reserves.
- Controller initial cost of \$ 250, Replacement of \$160 and operational and maintenance cost of \$40.
- •

RESULTS AND DISCUSSION

HOMER performed an hourly time series simulation for every possible system configuration on a yearly basis in order to evaluate the operational characteristics such as annual electricity production, annual load served, excess electricity, renewable fraction and so on. The renewable energy sources and diesel load generator were evaluated in order to determine the feasibility of the system. HOMER searched for optimum system configuration and component sizes that meet the load requirement at the lowest Cost (NPC) and then presents the results of the simulation in term of optimal systems and sensitivity analysis. The optimal results are categorized based on tile sensitivity variables chosen. Table 5 shows the system architecture in terms of kW rating of the array, wind turbine, diesel generator and the converter. The

number of batteries required for energy storage is also indicated under the system architecture. The conventional standalone diesel generator is presently employed in most rural areas in Nigeria, and hence considered as the base case simulation in this work. It is selected to allow a comparison to be made about the total savings that can be made by including a renewable energy source in the system design and implementation of hybrid power system (i.e comparing cost and emissions of DC with the proposed hybrid PV/wind/diesel/converter configuration). PV/diesel/battery/converter configuration is adjudged the optimal best in ikpa road, Abraka, EdibeEdibe, Okada and Wind/diesel/battery/converter configuration is adjudged the optimal best in Iwofe and Wilberforce island, and hence compared to the base case simulation with respect to NPC. RF, carbon emissions and diesel consumption for the diesel price (\$0.56/1).

Total NPC calculations

The NPC of all the feasible system configurations considered for implementation of hybrid power system in the selected sites are illustrated in for diesel price of \$0.56/1. NPC is calculated for the entire system based on the expected life of 20 years. The system configuration includes: Wind/ Diesel/ Battery/ converter, PV/ Wind/ Diesel/ Battery/ converter, Diesel/ Battery/ converter, PV/ Diesel/ Battery/ converter, PV/ Wind/ Battery/ converter, Diesel Standalone, Wind/ Diesel, PV/ Diesel/ converter, PV/ Wind/ Diesel/ converter, PV/ Battery/ converter, as results are shows in Table 4.

A		e onnununon re	JI all by bee	in comig	ii uuion		
System Configuration	Iwofe	Wilberforce	Ikpa	Okada	EdibeEdibe	Abraka	AVG.
		island	road				NPC
Wind/Diesel/Battery/converter	461369	459127	525469	528556	529358	519966	503974.2
PV/Wind/Diesel/Battery/	464248	464240	517604	519876	519033	507588	498764.8
converter							
Diesel/Battery/converter	510692	510692	510783	510783	510783	510588	510720.2
PV/Diesel/Battery/converter	513791	515055	502787	501767	502346	502576	506387
PV/Wind/Battery/converter	805118	767250	907906	915547	904874	886196	864481.8
Diesel	866926	866926	866926	866926	866926	866926	866926
Wind/Diesel	869541	869540	891667	891867	891816	890900	884221.8
PV/Diesel/converter	887894	888215	869537	869537	869537	869537	875709.5
PV/Wind/Diesel/converter	906534	906857	910273	910470	910420	909518	909012
PV/Battery/converter	1050000	1040000	898405	908390	893987	957751	958088.8
Wind/Battery/converter	1190000	1120000	N/A	N/A	N/A	2260000	-





Fig. 3 NPC for diesel price of \$0.56/1 for System configuration for ikpa road

+ € (N) € (N) € (N) € (N) € (N) € (N) E						Architect	une					Cost		System	Gen					N.	
Image: space spa	1 = =		Pi (kv	V V	G3 💙	Gen V	1kWh LA 😵	Converter V	Dispatch 😽		NPC V	Operating cost 😵	Initial capital V	Ren Frac V	Hours 😵	Production V (kWh)	Fuel V	O&M Cost V	Fuel Cost 😵	Capital Cost	Product
Image: 1 = 1 170 80 12.4 CC 51.6 4482.10 442.12 96.077 20 2.94 9.020 10.90 20.009 6.132 94.482 10.81 Image: 1 1 17.0 80 13.6 CC 51.11 149.170 48.386 20.0 2.94 9.020 10.90 20.009 6.132 9.434 13.1 Image: 1 17.0 80 13.5 CC 51.11 149.800 147.314 27.34 0.00 3.92 15.000 10.833 0.372 0.332	a 8	19 P	1			17.0	64	12.2	cc	\$1.07	\$480,330	\$45,929	\$24,082	0.0	3,622	56,699	17,069	30,787	9,559		
• ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■	a e	•	12	1		17.0	80	12.4	cc	\$1.08	\$482,110	\$42,182	\$63,077	20	2,354	36,280	10,950	20,009	6,132	36,448	18,857
Image: space	+ 🖀 🗉	• 2	11	.5	1	17.0	80	13.6	cc	\$1.11	\$498,972	\$43,345	\$68,386	20	2,304	36,008	10,843	19,584	6,072	34,511	17,855
Image: constraint of the state of	+ 🖀 8	• 2	3		1	17.0	64	11.5	cc	\$1.12	\$499,869	\$47,364	\$29,364	0.0	3,592	55,320	16,699	30,532	9,352		
Image: Constraint of the state stat	-					17.0			cc	\$1.94	\$866,926	\$87,043	\$2,261	0.0	8,760	54,840	20,611	74,460	11,542		
Image: Constraint of the state of	-	P	0.2	242		17.0		0.0306	cc	\$1.94	\$869,535	\$87,229	\$3,018	0.0	8,760	54,759	20,591	74,460	11,531	727	376
Image: space	+ =				1	17.0			cc	\$1.99	\$891,867	\$88,949	\$8,261	0.0	8,760	54,177	20,445	74,460	11,449		
★		-	50.	11			448	13.0	CC	\$2.03	\$892,442	\$66,625	\$230,599	100						150,363	77,793
🕂 📧 🛐 56.4 1 352 14.7 CC 52.10 5924.457 568.616 5242.638 100 168.345 87.65	+ 🕿		1.7	71	1	17.0		0.0414	CC	\$2.03	\$910,467	\$90,302	\$13,419	0.0	8,760	54,057	20,415	74,460	11,432	5,116	2,647
	+ =	III 💌	56.	4	1		352	14.7	CC	\$2.10	\$924,457	\$68,616	\$242,838	100						169,345	87,614

Fig. 4 NPC for diesel price of \$0.56/1 for System configuration for Okada

Architecture Converter v Dispatch V (5) NCC V Performance Architecture CONVERTING 18 CONVERTING 18 <thconverting 18<="" th=""> CONVERTING 18 C</thconverting>	savailable in Simulation R Cost (5) (5) (5) (5) (5) (7) 564,788 (3) 524,364 (9) 534,292 (7) 52,201 (6) 53,018 (8) 51,3419 (5) 5282,902 (3) 339,120	System System Ren Frac 1 18 2 0.0 2	Hours ♥ Pr 2,461 37 2,329 34 3,624 56 3,310 53 8,760 54 8,760 53 8,760 53	roduction ♥ Fu (kWh) ♥ (L) 7,097 11,1 4,915 10,7 5,757 17,7 3,977 16, 4,840 20,0 3,485 20,3 3,391 20,	Gen V 08/M Cost V (5) 20,918 888 19,796 8085 30,804 442 28,135 511 74,460 74,460 717 74,460	(\$) 5,929 9,588 9,039 11,542 11,532 11,352	Categorized (Capital Cost (\$) 34,875 33,877 727	Overall V Product (kWh 17,399 16,902			
Architecture Converter v (M) Dispatch v (M) COE (S) NPC (S) V (S) Perform (S)	Cost Initial capital (3) (5) (5) (5) (5) (7) 564,788 (3) \$22,81 (7) \$22,61 (0) \$3,018 (3) \$22,61 (3) \$3,018 (3) \$1,34,19 (5) \$282,902 (3) \$339,120	System Ren Frac 1 18 2 0.0 2 100 2	Hours ♥ Pro 2,461 37 2,329 34 3,624 56 3,310 53 8,760 54 8,760 53 8,760 53	roduction ♥ [U (LWh)) ♥ [U (0,097 11,1 4,915 10,1 5,757 17,1 3,977 16, 4,840 20,0 3,485 20,0 3,391 20,0	Gen (3) <th>€ Fuel Cost ¥ (5) 6,294 5,929 9,568 9,039 11,542 11,532 11,352</th> <th>Categorized () Capital Cost () (\$) 34,875 33,877 727</th> <th>Overall Product (kWh 17,399 16,902 362</th>	€ Fuel Cost ¥ (5) 6,294 5,929 9,568 9,039 11,542 11,532 11,352	Categorized () Capital Cost () (\$) 34,875 33,877 727	Overall Product (kWh 17,399 16,902 362			
Image: Convertion of the convertice of the convertion of the convertion of the	Cost Initial capital (5) (5) (5) 00 555,540 77 56,788 131 52,261 100 \$3,018 190 \$3,201 191 \$2,261 103 \$3,201 104 \$3,018 105 \$282,902 133 \$3289,120	System Ren Frac V (%) 18 2 0.0 2	Hours ♥ Pro 2,461 37 2,329 34 3,624 56 3,310 53 8,760 54 8,760 53 8,760 53	roduction ▼ Fue (kWh) ▼ Fue (L) ↓ 4,915 10,' 4,915 17,' 3,977 16,' 4,840 20,' 4,767 20,' 3,485 20,' 3,391 20,'	Gen C&A Cost (5) C&A Cost (5) C	Fuel Cost V (\$) 6,294 5,929 9,568 9,039 11,542 11,532 11,352	Capital Cost (\$) 34,875 33,877	Product (kWH 17,399 16,902			
Image: Constraint of the state of	Initial capital (5) Initial capital (5) (5) (5) (5) (5) (5) (5) (7) 564.788 (8) 534.292 (7) 52.261 (8) 53.018 (9) 53.018 (9) 53.261 (3) 52.42.902 (3) 53.91.201	Ren Fract I 18 1 23 2 0.0 3 0.0 4 0.0 4 0.0 4 0.0 4 0.0 4 0.0 4 0.0 4 100 400	Hours Print 2,461 37 2,329 34 3,624 56 3,310 53 8,760 54 8,760 54 8,760 53 8,760 53 8,760 53	Function (kWh) Function (L) 7,097 11, 4,915 10, 5,757 17, 3,977 16, 4,840 20, 4,767 20, 3,381 20,	I O&M Cost (\$) 239 20,918 388 19,796 3085 30,804 442 28,135 5511 74,460 593 74,460 271 74,460 247 74,460	Fuel Cost (5) 6,294 5,929 9,568 9,039 11,542 11,532 11,352	Capital Cost (\$) 34,875 33,877 727	Product (kWh 17,399 16,902			
↑ ↑ 1 0 0 0 100 <	(5) (5) (6) \$59,540 (7) \$64,788 (3) \$24,364 (9) \$34,292 (7) \$2,261 (6) \$3,018 (9) \$8,261 (3) \$13,419 (5) \$282,902 (3) \$329,120	(%) (%) (%) (%) (%) (%) (%) (%) (%) (%)	Hours V 2,461 37 2,329 34 3,624 56 3,310 53 8,760 54 8,760 54 8,760 53 8,760 53 8,760 53	(kWh) V (L) 7,097 11, 4,915 10, 6,757 17, 3,977 16, 4,840 20,0 4,767 20, 3,485 20, 3,391 20,	(s) (c) (c) (c) (c) (c) (c) (c) (c) (c) (c	(\$) V 6,294 5,929 9,568 9,039 11,542 11,532 11,352	(\$) 34,875 33,877 727	(kWh 17,399 16,902			
Image: Constraint of the	00 \$59,540 77 \$64,788 33 \$24,364 99 \$34,292 57 \$2,261 90 \$8,261 33 \$13,419 55 \$28,2902 33 \$32,9120	18 23 2 0.0 2 0.0 2 0.0 4 0.0 4 0.00	2,461 37 2,329 34 3,624 56 3,310 53 8,760 54 8,760 54 8,760 53 8,760 53	7,097 11., 4,915 10. 5,757 17./ 3,977 16. 4,840 20./ 4,767 20./ 3,391 20./	239 20,918 888 19,796 888 19,796 888 30,804 442 28,135 5511 74,460 593 74,460 2217 74,460	6,294 5,929 9,568 9,039 11,542 11,532 11,352	34,875 33,877 727	17,399 16,902			
↑ 1 11 10 10.7 CC 51.1 566,556 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,56 455,76 450,76 490,10	77 \$64,788 13 \$24,364 13 \$24,364 19 \$34,292 17 \$2,261 10 \$3,018 19 \$8,261 13 \$13,419 15 \$22,202 13 \$32,92,902	23 23 2 0.0 2 0.0 2 0.0 4 0.0 4 0.0 4 0.0 4 100	2,329 34 3,624 56 3,310 53 8,760 54 8,760 54 8,760 53 8,760 53	4,915 10,' 6,757 17,' 3,977 16,' 4,840 20,' 4,767 20,' 3,391 20,'	19,796 388 19,796 3085 30,804 442 28,135 511 74,460 593 74,460 221 74,460 247 74,460	5,929 9,568 9,039 11,542 11,532 11,352	727	16,902			
Image: Constraint of the state of the s	33 \$24,364 99 \$34,292 \$7 \$2,261 90 \$3,018 99 \$8,261 33 \$13,419 55 \$282,902 33 \$329,120	0.0 3 0.0 3 0.0 4 0.0 4 0.0 4 0.0 4 0.0 4 100	3,624 56 3,310 53 8,760 54 8,760 54 8,760 53 8,760 53	6,757 17, 3,977 16, 4,840 20, 4,767 20, 3,3485 20, 3,391 20,	30,85 30,804 142 28,135 511 74,460 593 74,460 271 74,460 247 74,460	9,568 9,039 11,542 11,532 11,352	727	362			
• • • 1 17.0 88 1.28 CC 51.15 569.149 540.194 • • • • • CC 51.9 51.13M 587.05 • • • • • • CC 51.9 51.13M 587.25 • • • • • • 0.0306 CC 51.9 51.13M 587.25 • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • • •	99 \$34,292 \$7 \$2,261 \$0 \$3,018 \$99 \$8,261 \$13,419 \$13,419 5 \$282,902 \$3 \$3,29,120	0.0 3 0.0 4 0.0 4 0.0 4 0.0 4 100 4	3,310 53 8,760 54 8,760 54 8,760 53 8,760 53	3,977 16, 4,840 20, 4,767 20, 3,485 20, 3,391 20,	142 28,135 511 74,460 593 74,460 271 74,460 247 74,460	9,039 11,542 11,532 11,352	727	362			
Image: Constraint of the	\$2,261 50 \$3,018 50 \$8,261 51 \$13,419 55 \$282,902 53 \$329,120	0.0 4 0.0 4 0.0 4 0.0 4 100 100	8,760 54 8,760 54 8,760 53 8,760 53	4,840 20, 4,767 20, 3,485 20, 3,391 20,	511 74,460 593 74,460 271 74,460 247 74,460	11,542 11,532 11,352	727	362			
Image: Constraint of the state of	i0 \$3,018 19 \$8,261 13 \$13,419 15 \$282,902 13 \$329,120	0.0 4 0.0 4 0.0 4 100	8,760 54 8,760 53 8,760 53	4,767 20, 3,485 20, 3,391 20,	593 74,460 271 74,460 247 74,460	11,532 11,352	727	362			
↑ 1 17.0 CC 51.9 51.16 \$88.90 ↑ 1 17.0 0.0414 CC \$2.03 \$11.80 \$90.30 ↑ 1 17.0 0.0414 CC \$2.03 \$11.80 \$90.30 ↑ 1 17.0 1.0 0.0414 CC \$2.03 \$11.80 \$90.30 ↑ 1 17.0 1.1 17.0 1.0 1.0 \$2.30 \$11.80 \$90.30 ↑ 1 15.1 5 55.2 16.3 CC \$2.30 \$13.90 \$85.91 ↑ 10 1 10 71.2 16.1 CC \$2.76 \$1.61.5 \$90.05 ↓ 10 1 18 99.2 22.4 CC \$5.95 \$3.47M \$218.77	99 \$8,261 93 \$13,419 .5 \$282,902 53 \$329,120	0.0 4 0.0 4 100	8,760 53 8,760 53	3,485 20,3 3,391 20,3	271 74,460 247 74,460	11,352		302			
	3 \$13,419 5 \$282,902 3 \$329,120	0.0 4	8,760 53	3,391 20,	247 74,460						
	5 \$282,902 33 \$329,120	100				11,338	5,116	2,553			
▼ €0 ₹7 712 16.1 CC \$2.76 \$1.61.M \$9906 ↓ €0 ₹7 78 992 22.4 CC \$5.95 \$3.47M \$218,7	\$329,120	100					153,759	76,711			
↓ 600 €2 78 992 22.4 CC \$5.95 \$3.47M \$218,7		100					206,174	102,861			
	02 \$639,196	100									
<								,			
							ОК	Cancel			
🚯 🖲 💽 🔝 🔂 📰 💽 🙆 🚞 4	7			_			.atl 🛱 6:4 11/2	4 PM 4/2017			
Fig. 5 NPC for diesel price of \$0.5	Fig. 5 NPC for diesel price of \$0.56/1 for System configuration for Abraka										

) Sele Choos	se a	lase base	Case e case	to compa	e with c	other syste	ems for econo	omic analysis. I	More detaile	d econon	nic compa	rison is available in	Simulation Resu	lts.						- 0	×
						Architectu	re					Cost		System			Gen		۲	Categorized 《	Overa PV
-			B 🖻	PV V	G3 🍸	Gen 🗸	1kWh LA 🍸	Converter	Dispatch 😽	COE V	NPC V	Operating cost	Initial capital	Ren Frac	Hours 😽	Production V	Fuel	O&M Cost	Fuel Cost	Capital Cost	Produ
-		. 1	13 P	0.442	4	17.0	80	21.0	сс	\$1.03	\$500,084	\$40,623	\$60,568	24	2,165	34,317	10,310	18,402	5,773	1,326	609
1	10	.	IB 🖻	0	4	17.0	72	21.0	сс	\$1.03	\$500,289	\$40,874	\$58,059	22	2,268	35,225	10,618	19,278	5,946		
	G	. 1	13 🖻	3		17.0	72	21.3	сс	\$1.12	\$548,219	\$47,495	\$34,348	0.0	3,552	57,239	17,150	30,192	9,604		
	G	.	IB 🖻	0.466		17.0	88	21.0	cc	\$1.13	\$550,038	\$47,339	\$37,859	0.0	3,414	56,200	16,781	29,019	9,398	1,399	643
	G	-				17.0			сс	\$1.94	\$946,132	\$87,239	\$2,261	0.0	8,760	54,840	20,611	74,460	11,542		
•	G			0.000154		17.0		0.240	сс	\$1.94	\$946,751	\$87,274	\$2,501	0.0	8,760	54,840	20,611	74,460	11,542	0.5	0.2
1	1	-			1	17.0			сс	\$1.99	\$968,863	\$88,785	\$8,261	0.0	8,745	52,301	19,962	74,332	11,179		
- 1	1	-		0.310	2	17.0		0.0579	cc	\$2.02	\$987,077	\$89,823	\$15,250	0.0	8,634	50,465	19,414	73,389	10,872	931	428
- 1	1	1	IB 🖻	55.4	4		440	14.4	cc	\$2.34	\$1.14M	\$80,409	\$270,557	100						166,132	76,34
			19 🖻	71.7			720	19.2	сс	\$2.97	\$1.45M	\$102,093	\$342,374	100						215,129	98,86
1	4	1	IB 🕅	0	32		1,208	14.1	cc	\$3.80	\$1.85M	\$135,280	\$387,328	100							
												п								ОК	Cance
										-	N										



	a second second			Cost		System			Gen				PV
💌 🛧 💼 🚥 💌 🙌 🟹 G3	3 V Gen V 1kWh LA V	Converter V Dispatch V		IPC V Operating cost	▼ Initial capital ▼ (\$)	Ren Frac	Hours 🟹	Production V	Fuel V	O&M Cost V	Fuel Cost	Capital Cost	۲ ۲
🛒 💼 🔀 13.4	17.0 80	11.4 CC	\$1.04 \$6	507,237 \$41,875	\$65,899	24	2,196	34,307	10,332	18,666	5,786	40,276	:
🕋 💷 💌	17.0 88	10.1 CC	\$1.05 \$6	513,131 \$45,453	\$25,530	0.0	3,436	56,377	16,843	29,206	9,432		
🏴 🛧 🖀 🖼 🔀 12.6 1	17.0 80	11.4 CC	\$1.08 \$6	528,815 \$43,280	\$69,307	24	2,204	34,321	10,341	18,734	5,791	37,668	1
ት 🖀 🖽 🔀 🛛 1	17.0 88	10.2 CC	\$1.09 \$6	533,979 \$46,591	\$31,669	0.0	3,355	55,016	16,438	28,518	9,205		
\$	17.0	CC	\$1.93 \$1	L13M \$87,057	\$2,261	0.0	8,760	54,840	20,611	74,460	11,542		
🛒 😰 0.242	17.0	0.0306 CC	\$1.94 \$1	L13M \$87,249	\$3,018	0.0	8,760	54,760	20,591	74,460	11,531	727	3
1	17.0	cc	\$1.99 \$1	L.16M \$89,001	\$8,261	0.0	8,760	54,141	20,435	74,460	11,444		
🛒 🛧 💼 🛛 🔀 1.71 1	17.0	0.0414 CC	\$2.03 \$1	L18M \$90,392	\$13,419	0.0	8,760	54,026	20,407	74,460	11,428	5,116	2
🏴 🔛 🔀 55.2	768	16.6 CC	\$2.53 \$1	L48M \$91,197	\$297,437	100						165,666	8
🚩 🛧 💷 🔀 55.2 1	752	15.1 CC	\$2.56 \$1	L49M \$92,076	\$299,392	100						165,522	8

Fig. 7 NPC for diesel price of \$0.56/1 for System configuration for EdibeEdibe



Fig. 10 NPC for all location and 10 system configurations

From the NPC analysis, it can be observed that stand-alone PV/Wind/diesel/battery/ converter system has the lowest NPC among the studied configuration for all the location when considering the average total NPC of each configuration in table 4. This study will be comparison will be mostly on Hybrid PV/Wind / Diesel/ Battery/ Converter system configuration. The wind system is not the best option because of the low wind speed at most of the sites. Fig. 11 and 12 show the graphical representation of NPC and COE respectively for PV/Wind/diesel/battery systems for all sites. In all the case of NPC calculation, \$1 N356, where \$ is US Dollars and N is Nigerian currency in Naira. The lowest 'NPC is obtained in Wilberforce Island, found in the tropical monsoon climatic zone. At \$0.56/L, the NPC is \$464240 and COE is \$1.03/kwh. The result shows the direct relationship between NPC and the level of components resources(solar radiation and wind speed), The higher the solar radiation in a site, the lower will be the NPC value, The higher the wind speed in a site, the lower will be the NPC value, This is because high irradiation will enable the PV system to supply the

load for a longer period, thereby reducing the operating hours of the diesel generator; this will bring about reduction in the diesel consumption and cost associated with diesel, which thus relates directly to low NPC.

Iwofe in the tropical wet climate is next to Wilberforce Island with value of \$464248, followed by Abraka which stands at \$507588NPC. The difference in average solar radiation and wind speed between these sites is found to be minimal. Okada, which represents the tropical climate, showed the highest NPC out of the six sites considered in the simulation. This is attributable to the low average daily global wind speed as found in this site compared to Wilberforce Island and Iwofe daily wind speed. The total NPC of Okada is \$519876; when compared to the base case NPC (i.e. diesel generator only), a saving of \$347050can be achieved.



Fig. 12 Graphical representation of COE for Hybrid Power System

System Architecture

Table 5 presents the number of components selected for most feasible configuration (PV/Wind/diesel/battery) in each state in south geopolitical zone of Nigeria, based on \$0.56/L diesel price considered. HOMER considered many factor such as global solar irradiation, global wind speed, diesel prices as well as load profile in coming up with this optimized number of system components. The component optimization process prioritizes continuous meeting of load demands by the hybrid system. This is aimed at ensuring marginal diesel consumption as well as making sure that PV system and wind turbine is not oversized. The space requirement for installation is also considered in the sizing of the batteries component.

Table -5 System Architecture for Calculations for Hybrid Pv/wind/diesel/battery/converter

Sensitivity case	Villages \$0.56/L						
	Abraka	Ikpa road	Wilberforce				
PV array (kw)	10.8	11.2	0.590				
Generator (kw)	17	17	17				
Wind turbine (kw)	1	1	4				
Converter (kw)	13.8	12.2	10.5				
Number of batteries	80	80	64				
	Okada	Iwofe	EdibeEdibe				
PV array (kw)	11.2	1.89	11.9				
Generator (kw)	17	17	17				
Wind turbine (kw)	1	4	1				
Converter (kw)	13.2	12.2	11.4				
Number of batteries	88	72	88				

The smallest component sizing in system architecture was obtained at Wilberforce Islandout of all the sites considered. The system architecture includes 0.59 kW solar panel, a 17 kW generator, a 10.5 kW converter and 64 batteries. It was noted from the simulation that most of the sites considered except EdibeEdibe, reported increase in the size of PV panel and batteries bank. This justifies the extra costs of installing a larger PV array and increasing the storage capabilities of the system in order to minimize the operating hours of the generator, thus keeping the NPC as low as possible.

RF Calculations

Renewable fraction varies as the system architectures for each site considered in the simulation. It can be observed from (Fig. 13) that RF for each site in the simulation is notably high for sensitivity case of \$0.56/1.Out of the six sites considered, Iwofe, Wilberforce and EdibeEdibe experience highRF value, the values are 0.29,0.26,0.22at \$0.56/L respectively. The lowest RF of 0.19 occurs in Okada for sensitivity case of \$0.56/I. Ikpa road and Abraka also experience a relatively low RF of 0.20 and 0.21 respectively for diesel price of \$0.56/1.

Carbon Emissions and Diesel Consumption

Annual CO_2 emissions relate directly to the amount of litres fuel consumed by the diesel generator per year. Fig. 14 shows a comparison to the total amount of diesel consumed per year by PV/diesel/battery configuration for each site with base case simulation at diesel price 0.56/1.



Fig. 13 RF for diesel price of \$0.56



Fig. 14 Diesel consumption ((L) for diesel price of \$0.56.

HOMER Pro Microgrid Analysis Tool	3.8.7 (Evaluation Edition)				
FILE	LOAD COMPONENTS	RESOURCES PROJECT HELP			
	imulation Results		A 3		
View	System Architecture:	Generic flat plate PV (10.803586 Generic 3 kW (1) Autosize Genset (17.000000 kW)	W) Generic 1kWh Lead Acid (10 strings) System Converter (13.8 kW) HOMER Cycle Charging	Total NPC: \$507,588.4 Levelized COE: \$1.1 Operating Cost: \$44,403.6	Calculate
4,845 solutions were simulated: 3,570 were feasible.	Cost Summary Cash Flow Generic 3 kW System Conv	Compare Economics Electrical verter Emissions	Fuel Summary Autosize Genset Renewable Penetra	tion Generic 1kWh Lead Acid Generic flat plate PV	Tabular Graphical onomics Column Choices
1.275 were infessible due to the capacity shortage constraint 1.234 were omitted: 0 due to infessibility. 588 for lacking a converter. 322 for having an unnecessary converter. 282 for no sources of power gent			Quantity Value Units Carbon Dioxide 28,038,28 kg/yr Carbon Monoxide 176,74 kg/yr Unburned Hydrocarbons 7,71 kg/yr Charbon Monoxide 107 kg/yr Carbon Monoxide 68,66 kg/yr Carbon Monoxide 68,66 kg/yr Charbon Monoxide 107 kg/yr Charbon Monoxide 68,66 kg/yr		Gen Hours Q Production Q Fuel Q C (456 38.846 11.675 2
SUGGESTIONS:			UNER MORE US	e	Categorized Overall
					Hours V Production V Fuel V (L) V
					2.269 35,593 10,711 3,625 56,715 17,075
	Report Copy		Time Series: Plot Sci	atter Plot Delta Plot Table Expor	t 8,494 53,854 16,255
		0.242 17.0	0.0306 CC \$1.94 :	\$869,537 \$87,229 \$3,018 0.0	8,760 54,840 20,611 8,760 54,760 20,591
🚳 🐐 🚺 ն		🔺 🧭 📀	•	Side and the second second	▲

Fig. 15 CO₂ Emission (kg/yr) for diesel price of \$0.56/1 for Abraka

D HOMER Pro Microgrid Analysis Tool	3.8.7 (Evaluation Edition)		Statement of the local division in the local		And in case of the local division of the loc		– 0 ×
FILE	LOAD COMPONENTS	RESOURCES PRO	DJECT HELP	4			
Home Design Results Libra	System Architecture:	Generic flat plate PV (Generic 3 kW (4)	(1.886494 kW) Generic 1kWh Lead Aci System Converter (12.2	d (9 strings) kW)	Total NPC: Levelized COE:	\$463,027.50 \$1.03	Calculate
		Autosize Genset (17.0	000000 kW) HOMER Cycle Charging		Operating Cost:	\$41,077.75	
5,718 solutions were simulated: 4,389 were feasible.	Cost Summary Cash Flow Generic 3 kW System Conv	Compare Economics erter Emissions	Electrical Fuel Summary Autosize	ienset Renewable Penetration	1 Generic 1kWh Lead Acid Ger	neric flat plate PV	Tabular Graphical Graphical Column Choices
1,329 were infeasible due to the			Quantity	Value Units			Company Economics
1,252 were omitted: 0 due to infeasibility.			Carbon Dioxide Carbon Monoxide Unburned Hydrocarbon	25,424.88 kg/yr 160.26 kg/yr 6.99 kg/yr			IRR V Simple Payback V Hour
588 for lacking a converter. 337 for having an unnecessary converter.			Particulate Matter Sulfur Dioxide Nitrogen Oxides	0.97 kg/yr 62.26 kg/yr 150.55 kg/yr			99 0.99 2,20
285 for no sources of power ge SUGGESTIONS: Check Autosize Genset O&M				USION US	~		Categorized Overall
				-6	2		Compare Economics
							99 0.99 2 90 1.1 2
	Report Copy		Time	Series: Plot Scatte	r Plot Delta Plot Tabl	e Export	163 0.61 3,
		0 V:20	13-19 17.0	CC \$1.94 \$8	72,570 535,010 5190 66.926 \$87,043 \$2.20	104 100 51 0.0	14 6.2 8 ~
💿 🕴 💽				1. 1	6 ¢0 5 6 /1 6 I	- C	

Fig. 16 CO₂Emission (kg/yr) for diesel price of \$0.56/1 for Iwofe

4.33 odditions were simulated 3.43 odditions were simulated 1.09 were invalued 1.09 were invalued 1.00 were invalu	Read Color Component Color Component Color Component Color Color Component Color Co	ture: Generic flat plate PV (1) Autosize Genset (17.00	CT HELP 11.192772 kW) Generic IkWh Lead Acid System Converter (13.2 00000 kW) HOMER Cycle Charging	l (11 strings) kW)	Total NPC: Levelized COE: Operating Cost:	\$519,875.70 \$1.16 \$45,462.84	Calcul
Report Copy Time Series: Plot Scatter Plot Delta Plot Table Export 4.40 55.228 10.560 Image: Statter Plot 10.0 0.0306 CC \$1.94 \$50.228 \$0.00 \$7.60 \$48.40 20.611 Image: Statter Plot 10.0 0.0306 CC \$1.94 \$869,537 \$87,229 \$3.018 0.0 \$7.60 \$44,80 20.611 Image: Statter Plot 10.0 10.00 \$1.94 \$869,537 \$87,229 \$3.018 0.0 \$7.60 \$4.80 20.611 Image: I	4,638 solutions were simulated: 3,543 were feasible. 1,095 were inseasible due to the capacity shortage contraint. 1,232 were omitted: 0 due to infeasibility. 586 for lacking a converter. 323 for having an unnecessary converter. 279 for no sources of power gen. SUGGESTIONS: Check Autosize Genset O&M c	sh Flow Compare Economics em Converter Emissions	Electrical Fuel Summary Autosize Ge Quantity Carbon Dinoxide Unburned Hydrocarbons Particulate Matter Syllin Dinoxide Nitrogen Gages	Nation Units 28/16.36 kg/yr 1810.1 kg/yr 100.1 kg/yr 100.2 kg/yr 100.4 kg/yr	Generic 1kWh Lead Acid Ger	eeric fiat plate PV	Tabular O Graphic enomics. Column Choices. Column Choices. Gen Gurs V Production V Ful (U V)))))))))))))))))))))))))
Image: Control of the state of th	Report	Сору	Time S	ries: Plot Scatter P	lot Delta Plot Tabl	e Export	3,440 55,238 16,560 750 54,840 20,611
		0.242	17.0 0.0306	CC \$1.94 \$869,5	37 \$87,229 \$3,018	0.0	8,760 54,760 20,591

Fig. 17 $CO_2Emission$ (kg/yr) for diesel price of \$0.56/1 for Okada

HOMER Pro Microgrid Analysis Tool	3.8.7 (Evaluation Edition)			-			
FLE Home Design Results Libra View	LOAD COMPONENTS mulation Results System Architecture:	RESOURCES PROJECT HE Generic flat plate PV (0.590493 kV Generic 3 kW (4) Autosize Genset (17.00000 kW)	N) Generic 1kWh Lead Acid (System Converter (10.5 k) HOMER Cycle Charging	8 strings) V)	Total NPC: Levelized COE: Operating Cost:	\$463,339.00 \$1.03 \$41,793.54	Calculate
CACCULATION HEPORT 5,533 solutions were simulated 4,413 were feasible. 1,440 were feasible to the capacity shortage constraint. 1249 were omitted. 0 due to infreasibility. 586 for lacking a converter. 334 for having an unnecessary converter. 365 for ins issues of power ge WOGESTIONS: Theck Autosize Geneet O&M	Cost Summary Cash Flow	Compare Economics Electrical erter Emissions	Vuel Summary Autosize Gee Quantity Carbon Dioxide Carbon Monoxide Unburned Hydrocarbons Pariculate Matter Suffür Dioxide Nitrodes Califer	Stress Renewable Penetration Value Units 26770.56 kg/yr 108.75 kg/yr 108.75 kg/yr 102 kg/yr 105.25 kg/yr 158.52 kg/yr 5% W/W	Generic 1kWh Lead Acid Ger	rerc: flat plate PV	Tabular Graphical namics. Column Choices Compare Economics Item (y) ISM V Simple Payback V (%) V (%) Simple Payback V (%) Categorized Overall Compare Economics Simple Payback V (%) Categorized Overall (%) Categorized Overall (%) Simple Payback V H (%) Overall Overall (%) Overall Overall
	Report Copy		Time Se	ries: Plot Scatter P	lot Delta Plot Tabl	e Export	02 1.2 2, 163 0.61 3, 16 5.7 0.2
		17.0		CC \$1.94 \$866	926 \$87.043 \$2.26	0.0	6:28 AM 11/27/2017

Fig. 18 CO₂Emission (kg/yr) for diesel price of \$0.56/1 for Wilberforce island



Fig. 19 CO₂ Emission (kg/yr) for diesel price of \$0.56/1 for EdibeEdibe

HOMER Pro Microgrid Analysis Too	3.8.7 (Evaluation Edition)						
FILE	LOAD COMPONENTS	RESOURCES PROJECT	HELP				
Design Results Library	Simulation Results		A 3				
View	System Architecture:	Generic flat plate PV (11.23)	783 kW) Generic 1kWh Lead Acid	(10 strings)	Total NPC:	\$517,604.30	Calculate
		Generic 3 kW (1)	System Converter (13.6 k	cW)	Levelized COE:	\$1.16	
CALCULATION REPORT		Autosize Genset (17.000000	kW) HOMER Cycle Charging		Operating Cost:	\$45,308.03	
4,547 solutions were simulated:	Cost Summary Cash Flow	Compare Economics Electr	cal Fuel Summary Autosize Ger	nset Renewable Penetration	Generic 1kWh Lead Acid	Generic flat plate PV	 Tabular O Graphical
3,545 were feasible.	Generic 3 kW System Con	verter Emissions					onomics Column Choices
1,002 were infeasible due to the			Quantity	Value Units			Gan
1 235 were omitted:			Carbon Dioxide	28,566.05 kg/yr			- Production - Fuel - (
0 due to infeasibility.		12	Carbon Monoxide	180.06 kg/yr			Hours V (kWh) (L)
588 for lacking a converter.		1	Unburned Hydrocarbons	7.86 kg/yr			2,334 37,094 11,139 1
323 for having an unnecessary			Particulate Matter	1.09 kg/yr			
converter.			Nitrogen Oxides	169.15 kg/yr			
282 for no sources of power gene			QUIN D	5.7			
SUGGESTIONS:			~ ~@	530			
Check Autosize Genset O&M c			~	410 m			
				OD no			•
							Categorized Overall
) E)		Ger.*
							Production - Fuel -
							Hours V (kWh) V (L) V
							2,334 37,094 11,139
							3,513 56,432 16,917
							2,320 36,237 10,913
	Report Copy		Time Se	ries: Plot Scatter	Plot Delta Plot	Table Export	3,422 54,793 16,434
		17.		CC \$1.94 \$000,	920 307,045	0.0	8,760 54,840 20,611
		0.242 17.	0.0306	CC \$1.94 \$869,	537 \$87,229	\$3,018 0.0	8,760 54,760 20,591 🖕
							•
A * O	A 🚺 🚞	🧭 👩 🚺			1000	State of the	▲







 CO_2 Emissions in kg/yr for the sensitivity cases at each site are shown in – Iwofesite consumed the least volume of diesel per year (9713L at diesel price \$0.56/I), while the highest volume of diesel consumption is observed at Okada. Comparing Fig 14 and Fig. 21: It shows that the hybrid renewable energy system configuration, provide a greater savings in CO_2 emission as the lower the volume of fuel consumed, the lower the CO_2 emitted (diesel generator system). Iwofe displays the lowest amount of CO_2 emission (25424.88 kg/yr). Followed by Wilber force island (26770.56 kg/yr) .The highest value of CO_2 emissions occurred at Okada, which stands at 28716.36 kg/yr for the sensitivity case of \$0.56 / 1.

Electrical	Abraka	EdibeEdibe	Okada Ikpa		Wilberforce	Iwofe
				road	island	
Generic flat plate PV(kWh/yr)	16704	18417	17299	17351	911	2907
AutosizeGenset(kWh/yr)	35593	35184	36518	36237	33245	31982
Generic 3Kw(kWh/yr)	2550	1217	4133	1414	21532	21066
Total(kWh/yr)	54847	54818	54950	55002	55688	55955
AC Primary load (kWh/yr)	45092	45092	45092	45092	45092	45092
Excess Electricity	210.9	175.9	84.1	178.5	2310.9	2172.6
Renewable Fraction	21.1	22	19	19.6	26.3	29.1

Wilberforce Island has the highest excess electricity of 2310.9kWh/yr which is 4.1% of total production as shown in table 7 while Iwofefollows as second highest with excess electricity of 2172.6kWh/yr which is 3.9% of total production while Okada has lowest excess electricity quantity of 84.1kWh/yr which is 0.2% of total production. The total Ac primary load for all the location is same having 45092kWh/yr consumption.

REFERENCES

- [1]. Bajpai, P. Dash, V. Hybrid renewable energy systems for power generation instand-alone applications: a review. *Renew Sustain Energy Rev* 2012; 16(5):2926/39.
- [2]. Dufo-Lopez, R. Bernal-Augustíne, J.L. Multi-objective design of ECN. Potentials for renewable energy application. Lagos: Gilspar Co. Ltd.; 1997.
- [3]. World Energy Outlook. 2016. Available from: http://www.worldenergyoutlook.org/resources/energy development/energyaccessdatabase/
- [4]. Hiendro A, Kurnianto R, Rajagukguk M, Simanjuntak. Y.M. Techno-economic analysis of photovoltaic/wind hybrid system for onshore/remote area in Indonesia. Energy 2013; 59:652.
- [5]. Kaldellis, J. K. Simotas, M. Zafirakis, D. Kondili, E. Optimum autonomous photo-voltaic solution for the Greek islands on the basis of energy pay-back analysis. J Clean Prod 2009; 17(15):1311-23.
- [6]. Chaurey, A. Kandpal, T.C. Assessment and evaluation of PV based decentralized rural electrification: an overview. Renew Sustain Energy Rev 2010; 14(8):2266-78.
- [7]. Kaldellis, J. Ninou, I. Energy balance analysis of combined photovoltaic/diesel powered telecommunication stations. Int J Electr Power Energy Syst 2011; 33(10):1739-49.
- [8]. Lambert, T. Gilman, P. Lilienthal, P. Micropower system modeling with HOMER. Integration Altern Sources Energy 2006;1(1):379-85
- [9]. Nnaji, C. Uzoma, C. Chukwu, J. The role of renewable energy resources in poverty alleviation and sustainable

development in Nigeria. Cont J SocSci2010; 3:317.

- [10]. Nandi, S. K. Ghosh, H. R. Prospect of wind/PV-battery hybrid power system as an alternative to grid extension in Bangladesh. Energy 2010; 35(7):3040-7.
- [11]. World Bank. 2014. Available from: http://data.worldbank.org.